

Influence of Host Tree Proximity on Adult Plum Curculio (Coleoptera: Curculionidae) Responses to Monitoring Traps

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ABSTRACT We evaluated responses of plum curculio, *Conotrachelus nenuphar* (Herbst), to baited and unbaited black pyramid and Plexiglas panel traps in mark–release–recapture experiments to determine whether presence of host apple trees diminishes trap effectiveness. Identical experiments were conducted in an open field (little competition present) and in an unsprayed apple orchard (presence of competition from natural host apple trees). Results of mark–release–recapture experiments were successful; we recaptured 21.0 and 2.9% in the field and orchard, respectively. Plum curculio response to traps was influenced by presence of apple trees, because significantly more recaptures were recorded in the field compared with the orchard. Pyramid traps recaptured more plum curculio in the field compared with the orchard and recaptured significantly more plum curculio compared with panel traps. Female plum curculio responded in significantly greater numbers to pyramid traps baited with benzaldehyde compared with unbaited traps in the field, but not under orchard deployment. Combined data indicate that positioning traps in proximity to host apple trees diminishes both trap and bait effectiveness either by direct competition from host tree stimuli or by physical obstruction of trap-related visual stimuli and/or volatile release. We conclude that an effective trap-based monitoring system for plum curculio will require better odor baits, trapping mechanisms, and/or deployment strategies that can overcome visual and olfactory interference presented by host apple trees.

KEY WORDS plum curculio, *Conotrachelus nenuphar*, monitoring traps, grandisoic acid, benzaldehyde

IDENTIFICATION OF ATTRACTIVE HOST plant volatiles and pheromones used by phytophagous pest species has become an important component of behaviorally based monitoring strategies (Foster and Harris 1997). In combination, host plant volatiles often synergize or enhance insect responses to sex and/or aggregation pheromones (Landolt and Phillips 1997). These enhanced responses have been recorded for a number of species belonging to the family Curculionidae (Landolt 1997) and have led to successful monitoring systems for several species, including *Rhynchophorus palmarum* (L.) (Oehlschlager et al. 1993), *Rhynchophorus cruentatus* (F.) (Giblin-Davis et al. 1994), and *Metamasius hemipterus sericeus* (Olivier) (Giblin-Davis et al. 1996).

The plum curculio, *Conotrachelus nenuphar* (Herbst), is a major pest of stone and pome fruit in eastern and central North America (Racette et al. 1992, Vincent et al. 1999) and is one of the most destructive pests of peaches and plums in the south-

eastern United States (Yonce et al. 1995). Lack of a reliable monitoring strategy to detect plum curculio appearance and/or abundance in orchards to determine need and timing of insecticide sprays (Prokopy and Croft 1994) has led to trap development and deployment for plum curculio (Teddars and Wood 1994; Yonce et al. 1995; Mulder et al. 1997; Prokopy and Wright 1998; Prokopy et al. 1999, 2000; Johnson et al. 2002; Leskey and Prokopy 2002). Furthermore, identification of potential baits for traps based on attractive host plant volatiles (Leskey and Prokopy 2000, Leskey et al. 2001, Prokopy et al. 2001) in conjunction with the attractive component of the male-produced aggregation pheromone, grandisoic acid (Eller and Bartelt 1996) also continues to be an area of active research.

Several trap types have been tested for plum curculio. The pyramid trap is believed to provide an attractive visual stimulus by mimicking a tree trunk (Teddars and Wood 1994, Mulder et al. 1997) and has been reported to capture more crawling than flying individuals (Prokopy and Wright 1998). Panel traps do not have a specific visual cue associated with them and are designed to capture flying adult plum curculio (Prokopy et al. 2000). The border row of fruit orchards would seem to be the ideal location for deployment of

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these monitoring traps because this is where adults first enter the orchard and oviposition damage first occurs (Racette et al. 1992). However, in studies in which pyramid and/or panel traps were deployed in the border row of untreated apple orchards, trap captures did not reflect amount of oviposition injury observed in fruit trees (Prokopy et al. 1999, 2000; Leskey and Wright 2004), and hence failed to serve as a reliable tool to determine need for and timing of insecticide application. A stronger correlation between trap captures and oviposition injury has been recorded in peach orchards in Arkansas and Oklahoma (Johnson et al. 2002).

A potential explanation for the poor relationship between trap captures and oviposition injury observed in these previous studies is that presence of host apple trees reduces the likelihood that foraging plum curculio will locate and enter monitoring traps due to physical, visual, and/or olfactory influence of host trees on baited monitoring traps. For example, Prokopy et al. (2000) reported that clear Plexiglas panels baited with synthetic fruit volatiles (ethyl isovalerate and limonene) placed 2 m from the woods and some distance from the orchard were significantly more attractive than unbaited panels, but they found no difference between baited and unbaited pyramid traps placed next to apple tree trunks or baited and unbaited cylinder traps placed in apple tree canopies in the border row. Furthermore, Piñero et al. (2001), reported that clear sticky Plexiglas panels and black pyramid traps placed in the border region between the woods and an unsprayed orchard captured a significantly greater number of plum curculio when baited with a synthetic fruit volatile, benzaldehyde, in combination with grandisoic acid compared with any other bait combination or to unbaited traps (with the exception of ethyl isovalerate and grandisoic acid during the early stages of plum curculio immigration). However, how plum curculio responded to these same bait combinations in the border row of an orchard was not tested. Thus, plum curculio responded in significant numbers to baited panel traps (Prokopy et al. 2000) and baited panel and pyramid (Piñero et al. 2001) traps compared with unbaited traps when traps were deployed adjacent to apple orchards, but not to baited traps in the border row of apple orchards themselves (Prokopy et al. 2000, Leskey and Wright 2004), indicating that presence of host apple trees may reduce trap effectiveness in or near the orchard.

The aim of this study was to determine whether presence of host apple trees is responsible for the inability of baited pyramid and panel traps to capture plum curculio after fruit set and provide an explanation for the inability of trap captures to reflect accurately the amount of oviposition injury observed in orchards (Prokopy et al. 2000). Mark-release-recapture experiments using plum curculio collected from wild populations were conducted at two sites: within an unsprayed apple orchard and within an open field. Responses to Plexiglas panel and black pyramid traps baited with either a synthetic fruit volatile (benzaldehyde), a synthetic male-produced aggregation

pheromone (grandisoic acid), benzaldehyde in combination with grandisoic acid, or unbaited controls were recorded at both study sites to assess the impact of host apple trees on recapture of plum curculio in traps. To be effective, a trap-based monitoring system must be able to overcome the natural inference provided by host apple trees. If presence of apple trees has no effect on monitoring traps, we predict that trap captures will be statistically equal between orchard and field locations.

Materials and Methods

Study Sites. Studies were carried out within an unsprayed section of a commercial apple orchard and an open field to provide study sites with and without competition from and/or physical disruption by host apple trees. The 6-ha commercial orchard was located in Inwood, WV, and planted in 1988. Trees were medium-size 'Empire' on M.9 rootstock planted ≈ 3 m apart within rows and 5 m between rows. The 2.5-ha field, planted in mixed fescue, was located at the Appalachian Fruit Research Station in Kearneysville, WV. A wood lot bordered the field to the north, whereas hedgerows bordered the field to the west and south, and a fence separating pastoral land with several rows of unmanaged apple trees bordered the field to the east. Groundcover at both sites was trimmed to a height of 10 cm for these studies to decrease the potential influence of other nonhost vegetation. Sites were located within 15 km of each other and experienced similar weather conditions.

Trap Types. We evaluated two trap types in both locations: 1) black pyramid traps originally designed to monitor pecan weevil, *Curculio caryae* (Horn), populations (Teddars and Wood 1994) but modified to monitor plum curculio (Prokopy and Wright 1998, Prokopy et al. 1999); and 2) Plexiglas panel traps (Dixon et al. 1999, Prokopy et al. 2000, Piñero et al. 2001) coated on one side with Tangletrap (Gempler's, Belleville, WI). We deployed two trap types to allow capture of both crawling (pyramid traps) or flying (panel traps) plum curculio, although pyramid traps also may capture flying adult plum curculio (Prokopy and Wright 1998, Dixon et al. 1999).

Baits. We evaluated traps baited with one of four bait treatments: 1) the synthetic fruit volatile benzaldehyde (Aldrich, Milwaukee, WI), found to be attractive to plum curculio (Piñero et al. 2001, Prokopy et al. 2001); 2) grandisoic acid (ChemTica International, S.A., San Jose, Costa Rica), a synthetic version of an attractive component of the male-produced pheromone (Eller and Bartelt 1996); 3) benzaldehyde in combination with grandisoic acid; and 4) an unbaited control treatment. Release rate of benzaldehyde dispensers (500 μ l of benzaldehyde in 1-ml white, UV-resistant, low-density polyethylene vials (Wheaton Scientific Products, Millville, NJ) was ≈ 10 mg/d; release rate was determined by exposing 25 dispensers to open-air outdoor conditions at 25–30°C for 96 h and weighing each dispenser daily to determine milligrams of compound lost per day over the 4-d

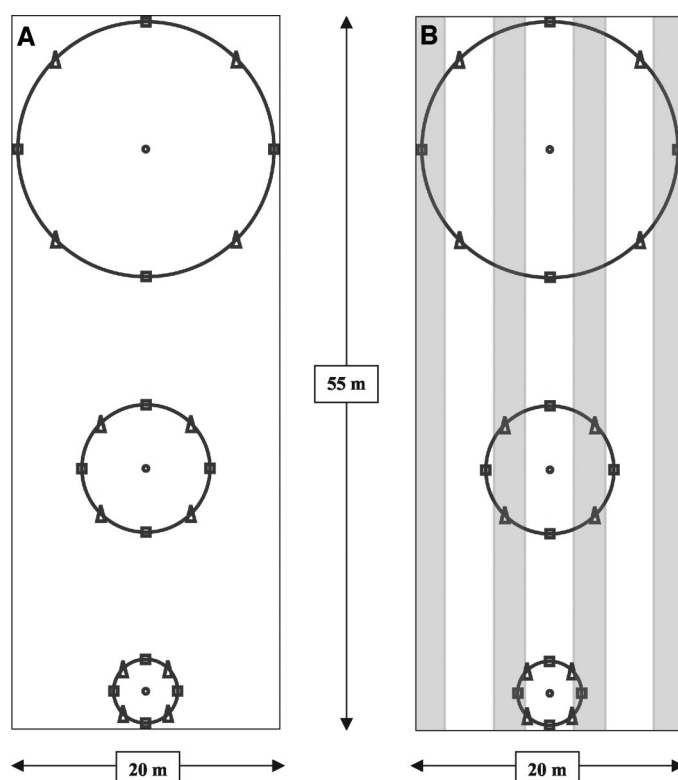


Fig. 1. Experimental layout of alternating pyramid and panel traps at the border of circular subplots of increasing diameter (5, 10, and 20 m) in (A) field and (B) apple orchard (stripes represent tree rows within the unsprayed apple orchard).

period. Release rate of grandisoic acid dispensers (25 mg) was determined by the manufacturer to be ≈ 1 mg/d. For pyramid traps, baits (a single benzaldehyde dispenser and/or a single grandisoic acid lure) were placed within the boll weevil trap collection device located at the top of each trap. For panel traps, a single benzaldehyde dispenser was attached to the edge of each panel using a locking plastic cable tie and/or a single grandisoic lure was attached to the upper right-hand corner of the panel with a small binder clip.

Block Setup. We established 55 by 20-m blocks in both the open field and apple orchard. Within each block, three sets of alternating pyramid and panel traps (four of each trap type in each set) were installed in three circular subplots of increasing diameter (5, 10, and 20 m) (Fig. 1). Traps were spaced equidistantly along the perimeter of each circular subplot. Each of the three circular subplots was divided into four quadrants; each quadrant contained a pyramid and panel trap baited with one of the four baits being tested. Within the apple orchard subplots, trees that had traps located next to them within the tree row were pruned to accommodate the trap and provide ≈ 1 m of open space. Within the field block, the potential influence from host trees was minimized by providing at least a 100-m buffer surrounding the test block that was free of any known host tree species of plum curculio (Maier 1990).

Plum Curculio Adults. Plum curculio used in these experiments were collected in Jefferson and Berkeley counties in West Virginia. In late May, these overwintered adults were collected from populations present in unsprayed fruit trees using beating sticks and collection sheets placed beneath tree canopies. Plum curculio were assumed to be approximately the same age, segregated according to sex within 24 h after collection by using criteria described by Thomson (1932), and held as separate sexes in wax-coated cups (473 ml) with clear plastic lids at 25°C under a photoperiod of 16:8 (L:D) h to mimic long-day conditions in nature from late May to late June. On average, 40 single-sex individuals were housed within a cup. Fresh apple fruit was provided along with a wetted cotton wick as a water source. Although some herbivorous insects respond to olfactory stimuli differently based on diet provided before experimentation, no such response was observed with plum curculio in previous studies involving plum curculio attraction to synthetic host volatile attractants (Leskey and Prokopy 2001). Before release, adults were starved for 24 h [because this protocol was previously shown to enhance responsiveness to olfactory stimuli with no negative physiological effects (Prokopy et al. 1995)] and marked with a small uniquely colored dot of paint on their elytra to designate sex, release point, and sample interval. This marking technique was similar to that

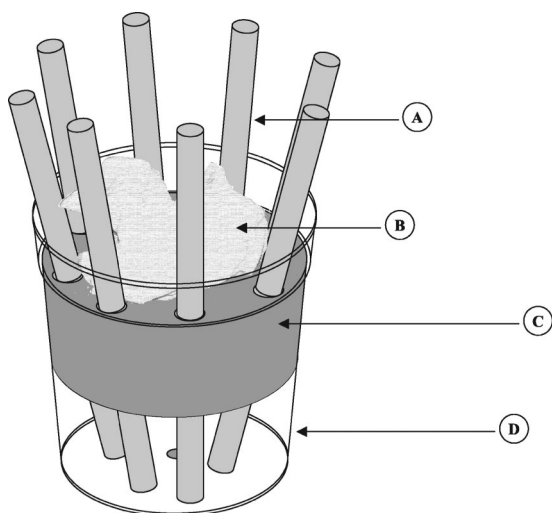


Fig. 2. Release device used to facilitate plum curculio movement from central release point in each circular subplot. Release device consisted of (A) wooden dowels inserted into a (C) florist foam plug held within a (D) plastic cup. Chilled plum curculio were released in conjunction with a (B) paper towel to provide shelter and diminish escape responses.

used by Butkewich and Prokopy (1997) in mark-release-recapture experiments of adult plum curculio.

Before release, plum curculio were chilled for 30 min inside wax-coated paper cups with moistened paper towels over an ice bucket to diminish escape responses. Plum curculio were released in groups of 40 (20 males and 20 females) in the center of each of the three circular subplots. The contents of each cup (plum curculio and paper towels) were gently removed and placed in the center of a release device consisting of a modified plastic cup with attached wooden dowels inserted into a plug of florist foam (Fig. 2). Wooden dowels promoted plum curculio movement from the release device by providing a substrate for either crawling or flight. With the exception of two plum curculios in the open field block, all plum curculios moved from the release devices into subplots.

All recovered females were dissected in the laboratory to determine mating status and sexual maturity. Female mating status was determined by removal of the spermatheca for immediate wet mount on a glass slide to establish presence or absence of sperm using a Nikon SMZ 1500 (7.5–112.5 \times) stereomicroscope. Sexual maturity was determined by criteria described by Smith and Salkeld (1964), specifically presence of mature eggs in calyx and developing oocytes in the vitellarium.

Trap Inspection. Traps were inspected 24, 48, 72, and 96 h after release at \approx 1800 hours. Recaptured plum curculio were removed from traps and taken back to the laboratory to determine mating status and sexual maturity of all females recovered. Before the next release of plum curculio in each circular subplot,

traps were rotated clockwise by one quadrant to account for any positional bias and baits were replaced. All releases were made after petal fall (1 May) because it is after this phenological event when plum curculio captures by baited traps begin to decline and developing fruit are at risk for oviposition injury (Prokopy et al. 2000). Releases were made on 16 May, 23 May, 27 May, and 4 June 2001 when apple fruit were \approx 12, 20, 22, and 30 mm in diameter, respectively, at \approx 1800 hours at both locations.

Data Analysis. Analysis of covariance (ANCOVA) was conducted using the SAS PROC GLM procedure (SAS Institute 2001) (treating subplot size as a covariate) to determine which class variables (location, trap type, bait, sex, release event, and quadrant) significantly influenced plum curculio recaptures across and within orchard and field sites. This particular analysis provided a means to test the effects of all qualitative class variables on the dependent variable (plum curculio recaptures) while controlling for effects of variation contributed by the quantitative variable (subplot size) (SAS Institute 2001). For those factors found to be significant, data were analyzed for that particular factor using a two sample *t*-test (location, trap type, and sex) to determine whether significant differences existed between means. The relationship between temperature (daily maximum, minimum, and average) and daily recaptures within the field and the orchard was analyzed in separate analyses (treating temperature as a quantitative variable using the SAS PROC GLM procedure); none of these models were significant. Analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) were conducted using the SAS PROC GLM procedure (SAS Institute 2001) to determine whether either male or female plum curculio responded significantly to any particular bait deployed with either pyramid or panel traps within orchard and field sites at each distance.

Results

Recapture Profiles. The percentages of marked plum curculio recaptured were 21.0 and 2.9% in the field and in the orchard, respectively, across all releases. Within the field, recapture rates were 39.4, 15.6, and 8.0% for the 5-, 10-, and 20-m subplots, respectively. Within the orchard, recapture rates were 7.5, 1.3, and 0.0% for the 5-, 10-, and 20-m subplots respectively. More than 75% of all recaptured adults were recovered within 2 d of release in all subplots located in both the field and in the orchard with one exception: 10-m subplot located within the orchard (Table 1). Within the orchard block, 11 wild adults were captured indicating that the mean \pm SE size of the wild population within that area was 263.50 ± 43.96 according to the Lincoln Index.

Across Sites. We recaptured a total of 115 plum curculio. The general linear model for trap recaptures was significant ($F = 9.50$; $df = 13, 370$; $P < 0.001$). Release event, quadrant, and sex of released plum curculio did not have significant effects on recapture

Table 1. Cumulative percentage of mean recovery and cumulative number of marked plum curculio adults recaptured in field and orchard subplots over 4-d recovery period

	Field			Orchard		
	5 m % (n)	10 m % (n)	20 m % (n)	5 m % (n)	10 m % (n)	20 m % (n)
Day 1	60.3 (38)	48.0 (12)	46.2 (6)	58.3 (7)	0.0 (0)	0.0 (0)
Day 2	81.0 (51)	88.0 (22)	76.9 (10)	91.7 (11)	50.0 (1)	0.0 (0)
Day 3	95.2 (60)	100.0 (25)	76.9 (10)	91.7 (11)	100.0 (2)	0.0 (0)
Day 4	100.0 (63)	100.0 (25)	100.0 (13)	100.0 (12)	100.0 (2)	0.0 (0)

The *n* value at day 4 for each subplot reflects total number recaptured out of 160 released individuals.

results (Table 2). Location, however, was significant (Table 2) with more plum curculio recaptured per trap in the field (mean \pm SE, 0.53 ± 0.08) than in the orchard (0.07 ± 0.02) ($t = 5.787$; $df = 1, 382$; $P < 0.0001$). Trap type also was significant (Table 2) with significantly more plum curculio recaptured in pyramid than in panel traps (0.54 ± 0.08 and 0.06 ± 0.02 , respectively) ($t = 7.06$; $df = 1, 382$; $P < 0.0001$). Bait type was not significant across sites (Table 2) and the covariate, subplot size, was significant (Table 2) with more plum curculio recaptures in the 5-m-diameter subplots (0.58 ± 0.01) compared with 10- or 20-m subplots (0.21 ± 0.05 and 0.01 ± 0.03 , respectively).

Within Orchard. Within the orchard, we recaptured a total of 14 plum curculio. The general linear model of trap recaptures was significant ($F = 2.65$; $df = 12, 179$; $P = 0.0027$). Bait, release event, and quadrant did not have significant effects on trap recaptures (Table 3). However, the effect of sex was significant (Table 3) with more males captured per trap (mean \pm SE, 0.11 ± 0.04) than females (0.03 ± 0.02) ($t = 1.951$; $df = 1, 190$; $P = 0.0526$). Trap type also was significant (Table 3) because more plum curculio were recaptured in pyramid (0.11 ± 0.04) than in panel traps (0.03 ± 0.02) ($t = 1.951$; $df = 1, 190$; $P = 0.0526$). Finally, there was a significant effect of the covariate, subplot size (Table 3) with more recaptures in the 5-m subplot (0.19 ± 0.06) than in the 10 m (0.03 ± 0.02) and 20 m (0.00 ± 0.00) subplots. Recaptures from baited and unbaited pyramid or panel traps for either females and/or males were not significantly different at any distance.

We captured a total of 11 wild individuals in the orchard, 10 of which were captured in baited traps (eight in pyramid and two on panel traps). However, no significant difference was detected among baits.

Table 2. One-way ANCOVA for effects of class variables on recapture results of marked-released adult plum curculio across field and orchard sites

Test Variable	<i>F</i> value	df	<i>P</i> value ^a
Bait	1.64	1,370	0.1786
Location	39.77	1,370	<0.0001
Quadrant	0.68	3,370	0.5661
Release event	0.97	3,370	0.4059
Sex	0.01	1,370	0.9423
Subplot size ^b	30.30	1,370	<0.0001
Trap type	43.51	1,370	<0.0001

^a Probability of a type III error.

^b Covariate.

Within Field. We recaptured a total of 101 plum curculio at our field site. The general linear model for trap recaptures was significant ($F = 6.35$; $df = 12, 179$; $P < 0.0001$). Sex, release event, quadrant, and bait did not have significant effects on trap captures across all subplots (Table 4). However, trap type was significant (Table 4) with more plum curculio recaptured in pyramid (mean \pm SE, 0.96 ± 0.13) than in panel traps (0.09 ± 0.03) ($t = 6.296$; $df = 1, 190$; $P < 0.0001$). Again, the covariate, subplot size, was significant (Table 4); more plum curculio were recaptured per trap in the 5-m-diameter subplot (0.98 ± 0.18) compared with 10- and 20-m subplots (0.39 ± 0.10 and 0.20 ± 0.06 , respectively). More than 58% of all recaptures in the field were in pyramid traps positioned in the 5-m subplot. Within the same subplot, recaptures across pyramid traps containing different baits were significantly different for females, but not for males (Table 5). Significantly more females were recaptured in pyramid traps baited with benzaldehyde compared with unbaited traps (Table 5). At all other distances, recaptures from baited and unbaited pyramid and panel traps for either females and/or males were not significantly different.

Mating Status. We recaptured a total of 57 females, 54 in the field and three in the orchard. We were able to determine mating status and sexual maturity of 51 females recovered from the field and three females recovered in the orchard; of these, 92 and 100% were mated and sexually mature, respectively.

Discussion

The objective of our study was to determine whether presence of host apple trees compromises the attractiveness and effectiveness of baited and unbaited traps for plum curculio, resulting in perilous

Table 3. One-way ANCOVA for effects of class variables on recapture results of marked-released adult plum curculio in orchard subplots

Test variable	<i>F</i> value	df	<i>P</i> value ^a
Bait	1.12	3,179	0.3393
Quadrant	0.26	3,179	0.8540
Release event	1.81	3,179	0.1449
Sex	4.14	1,179	0.0428
Subplot size ^b	13.97	1,179	0.0002
Trap type	4.14	1,179	0.0428

^a Probability of a type III error.

^b Covariate.

Table 4. One-way ANCOVA for effects of class variables on recapture results of marked-released adult plum curculio in field subplots

Test variable	F value	df	P value ^a
Bait	1.44	3,179	0.2330
Quadrant	0.64	3,179	0.5919
Release event	0.48	3,179	0.6939
Sex	0.52	1,179	0.4762
Subplot size ^b	23.98	1,179	<0.0001
Trap type	44.35	1,179	<0.0001

^a Probability of a type III error.

^b Covariate.

reduction of captures under orchard conditions. Indeed, we recorded significantly fewer recaptures in the orchard compared with the field (Table 2) with nearly an eightfold difference between the mean \pm SE number of plum curculio captured per trap in the field (0.53 ± 0.08) compared with the orchard (0.07 ± 0.02). Our results indicate that plum curculio are less likely to locate and/or enter baited and unbaited pyramid and panel traps in the presence of host apple trees.

The impact of host apple trees could be described in terms of the types of stimuli they provide foraging plum curculio. For example, many phytophagous insects use visual stimuli to aid them in host plant finding (Jolivet 1998). In host apple trees, dimensional features of the trunk and upright limbs (Leskey and Prokopy 2002) are likely important to plum curculio because many phytophagous insects respond to tall narrow dimensions of vertically growing plant structures (Prokopy and Owens 1983). This type of visual cue has been used to create monitoring traps for plum curculio. The black pyramid traps used in our studies originally were designed to capture the pecan weevil and are believed to exploit responses to visual cues provided by the tree trunk (Teddars and Wood 1994, Mulder et al. 1997). We hypothesized that if presence of host apple trees interferes with visual stimuli provided by pyramid traps, then recaptures should be lower in the orchard compared with the field. In our studies, we observed a nearly ninefold drop in average number of plum curculio recaptured in black pyramid traps placed in our orchard (0.11 ± 0.04 plum curculio per trap) compared with the field (0.96 ± 0.13 plum curculio per trap). Given that groundcover was iden-

tical between field and orchard (trimmed to a height of 10 cm), the host trees may be interfering with the visual stimulus provided by traps. Perhaps natural visual stimuli of host apple trees such as spectral qualities and/or specific dimensional characteristics (Prokopy and Owens 1983) were more attractive to plum curculio than stimuli provided by black pyramid traps. Alternatively, the presence of dense apple foliage, limbs, and trunks in the orchard simply may have obscured the pyramid trap, from the line of vision of plum curculio. Under either circumstance, the results highlight a decrease in effectiveness of this particular visual cue in the context of an orchard.

Host apple tree odor is known to be attractive to plum curculio (Butkewich and Prokopy 1997, Leskey and Prokopy 2000). Benzaldehyde, the synthetic attractant used in our study, was identified from both apple blossoms (Buchbauer et al. 1993) and immature plum (Leskey et al. 2001) and was found to be attractive to plum curculio under field conditions, especially when combined with the aggregation pheromone grandisoic acid (Piñero et al. 2001). Given that the principal attractant used in our study, benzaldehyde is a host plant-produced compound, we predicted that plum curculio would discriminate between baited and unbaited traps in the field, but not in the orchard due to competition from natural host apple tree odor. Indeed, we observed no significant difference among baited and unbaited traps in any of the orchard subplots for either trap type from either sex of plum curculio. We only recaptured a total of 14 adults in the orchard, 12 of which were recaptured in the 5-m subplot. As predicted, we were able to detect discrimination among baited traps in our 5-m field subplot. Here, significantly more female plum curculio were recaptured by pyramid traps baited with benzaldehyde compared with unbaited pyramid traps. Pyramid traps baited with benzaldehyde in combination with grandisoic acid or with grandisoic acid alone were intermediate in terms of their attractiveness (Table 5). Thus, it seems possible that plum curculio response to baited traps was diminished due to presence of competition by natural host apple tree odor. Similar results have been reported for an attractant available to monitor codling moth, *Cydia pomonella* (L.). The attractant ethyl (2*E*,4*Z*)-2-4-decadienoate (a pear-derived volatile) was highly attractive to codling moth in walnut and apple (in the early part of the season) orchards, but was less attractive in pear and apple orchards (in the latter part of the season), owing to the olfactory competition from the same or similar esters likely released by maturing or damaged fruit (Light et al. 2001).

However, we cannot dismiss an alternative hypothesis to explain these results, i.e., volatile plumes emanating from baited traps in the orchard were simply obscured and/or physically disrupted due to the presence of apple trees, creating variation in air movement and microenvironment surrounding traps compared with conditions found in the open field. Physical features of a particular habitat have influenced trap captures for other weevil species. For example, the boll

Table 5. Mean number of male and female plum curculio recaptured by baited pyramid traps in 5-m field subplot

Bait	n	Male	Female
		Mean \pm SE ^a	Mean \pm SE ^b
Benzaldehyde	4	1.25 \pm 0.25a	4.00 \pm 0.71a
Benzaldehyde + grandisoic acid	4	2.00 \pm 1.08a	2.25 \pm 0.95ab
Grandisoic acid	4	2.00 \pm 1.08a	1.50 \pm 0.50ab
Unbaited	4	1.25 \pm 0.63a	0.50 \pm 0.50b

^a Values are not significantly different according to one-way ANOVA ($F = 0.27$, $P = 0.85$).

^b Values are significantly different according to one-way ANOVA ($F = 4.60$, $P = 0.023$) and Tukey's HSD.

weevil, *Anthonomus grandis grandis* Boheman, is considered to be weak-flying species. Sappington and Spurgeon (2000) found that variation in daily trap captures was related to daily variation in synoptic wind speed. Furthermore, captures in traps located on either side of a wind break were influenced by the effects produced by the local vegetation structure on air flow. A means to test the hypothesis that host apple trees simply obscured or disrupted ability of plum curculio to locate our baited monitoring traps would be to set up an experiment in a planting of nonhost trees with similar architecture and spacing to that found within our experimental orchard. If results observed within the orchard were due to the physical features of the host apple trees themselves, we would expect to observe identical results in a nonhost tree planting. This same hypothesis also would apply to the potential impact of visual obstruction from host apple trees. Although we did not test this hypothesis specifically in our studies, other studies have deployed traps outside orchards along the edge of wood lots, where presumably, olfactory and visual cues presented by baited monitoring traps were at least somewhat physically obstructed by nonhost tree species. In these studies, discrimination between baited and unbaited traps was recorded (Prokopy et al. 2000, Piñero et al. 2001), but when baited traps were deployed within an orchard, discrimination was not observed (Prokopy et al. 2000), indicating that at least to some degree, particularly at close range (within 1–2 m) competition from host apple trees must influence the ability of plum curculio to locate and/or enter baited monitoring traps.

More importantly, our results highlight an even greater problem—our inability to capture mated, ovipositing females in our monitoring traps to reliably predict damaging potential of a population. Of those females recaptured in our experiments, nearly all were mated with mature eggs in the calyces. In the field, we were able to recapture 54 females, but only three in the orchard. Furthermore, we recaptured significantly more males than females in the orchard (Table 3), but not in the field (Table 4). Thus, to effectively monitor plum curculio and more accurately predict damage potential, a baited monitoring trap must be capable of attracting and capturing ovipositing females after fruit set, the phenological period when traps lose their effectiveness and the damage potential of a population increases (Prokopy et al. 2000). Thus, our results explain why trap captures recorded for pyramid and/or panel traps deployed in the border rows of orchards declined after fruit set, failed to reflect amount of oviposition injury observed in fruit trees, and therefore failed to serve as reliable tools to determine need for and timing of insecticide application (Prokopy et al. 1999, 2000; Leskey and Wright 2004).

Although progress has been made in terms of identification of attractive host plant-based attractants (Leskey and Prokopy 2000, 2001; Prokopy et al. 2000; Leskey et al. 2001; Piñero et al. 2001), identification of an attractive component of the male-produced pheromone (Eller and Bartelt 1996), and development of

potential traps (Tedders and Wood 1994; Mulder et al. 1997; Prokopy and Wright 1998; Prokopy et al. 1999, 2000; Leskey and Prokopy 2002), competition from and/or physical obstruction by host trees significantly decreases capture of plum curculio. Deploying baited monitoring traps some distance away from the orchard itself (Prokopy et al. 2000, Piñero et al. 2001) may be one method for increasing effective detection of plum curculio immigration into orchards but our inability to predict potential injury to fruit based on trap captures remains a serious issue. Thus, a second method could be to deploy a larger number of traps to increase chances of plum curculio capture. A third method proposed to overcome weaknesses associated with monitoring traps is that of a “trap tree” approach that uses semiochemical cues to aggregate plum curculio and oviposition damage to a particular host tree to make management decisions (Prokopy et al. 2003). As with development of a trap-based curculio monitoring strategy, this approach must reliably overcome competition from and/or obstruction by unbaited, attractive host trees. Our findings suggest that plum curculio trap captures decrease significantly when traps are located within an orchard and we conclude that an effective monitoring system for plum curculio will require baited traps that can compete with host apple tree stimuli and/or that greater numbers of baited traps be deployed to more reliably capture adult plum curculio and predict damage potential, ultimately to determine need and timing of insecticide application.

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